
Space Weather Technical Forecast

Issued on Saturday, 20 May 2023 at 01:18 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales <https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales>

Space Weather Forecast Headline: R1/R2 Likely. Slight Chance of G1 from later in UTC weekend.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been High over the past 24 hours, with X-ray activity recorded at GOES16 showing several M-class flares, these mostly originating from AR3311. The largest of these was an impulsive M5.2 observed at 19/0048UTC from AR3311.

There are currently around seven sunspot regions on the visible disc, with AR3307, 3309 and 3301 all fading to plage in the period, while AR3311, 3312 and 3313 were numbered. In addition to these new spots, a small bipolar region may now also be developing narrowly in advance of AR3311.

Of the current cohort of spot groups, AR3311 is the largest and most complex, with a Zurich Esc classification easily attained. The Mt Wilson classification of Beta-Gamma is less certain due to the narrow viewing angle hindering magnetic polarity observations in the group's many penumbrae, but it may also contain a Delta. AR3310, which gave an M9.6 on 16 May is large but less complex overall, with its main penumbral leader dominant in terms of area, but with little else in its ambit it remains a Cko/Beta. Many of the other regions on the disc were smaller dipoles or else unipolar groups, while the main changes were confined to AR3305, which saw proliferation of its intermediate spots for a time, with this succeeded by a spreading tendency later in the UTC day.

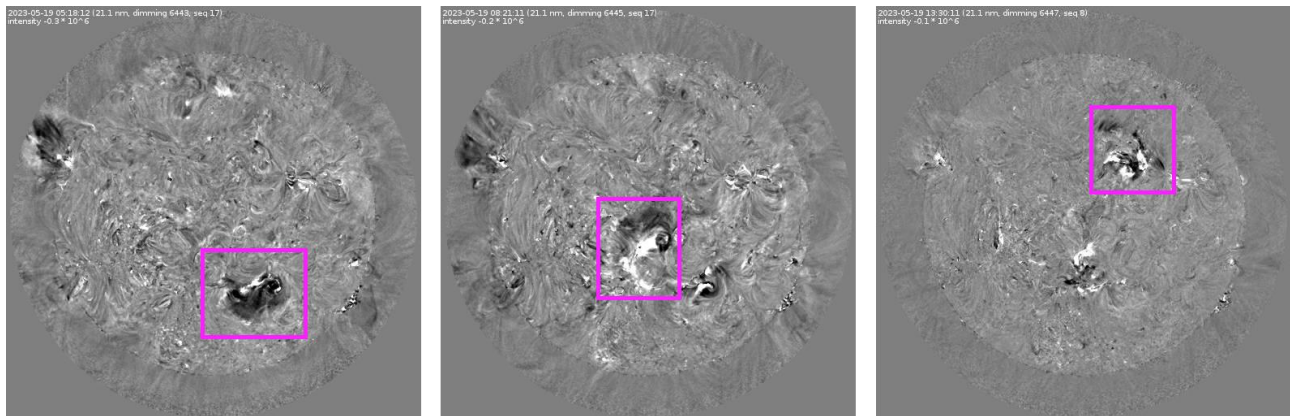


Figure 0: Three of the more noteworthy filament-related events on the disc in the past 24 hours, although as yet none of these has produced a confirmed Earth-directed CME. The above are all time-integrated AIA211 dimmings processed by SIDC ROB.

The solar disc has seen numerous filaments become mobile or else disappear in the past 36 hours or so. Perhaps the most relevant observed in the 24-hour period were one from the southwest disc at 19/0530UTC, which produced a CME seen heading largely south and west of the track of the Earth's orbit. This has been modelled as a miss. This in turn sparked movement in a more central

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filament from 19/0830UTC, with this feature remaining mobile for several hours following, but perhaps not resulting in any lift-off, with no obvious subsequent ejecta on coronagraphs. Thirdly, in the northwest disc, another filament disappeared around 19/1300UTC, as seen on H-Alpha imagery. This may be the progenitor of a narrow and faint CME heading north and west in coronagraph imagery, although its appearance is perhaps too immediate. Whatever the cause of this CME, provisionally it appears too narrow, north and west to have any bearing on conditions at Earth, with modelling results awaited.

No new Earth-directed CMEs were therefore in evidence at the time of writing, although confidence in this statement is lower than typical given the weight of events.

Solar Wind / Geomagnetic Activity: The solar wind, as measured by ACE at L1, was suggestive of a slow regime for much of the period, however this transitioned into a CIR-like environment during the UTC evening, possibly a precursor to anticipated CH03/-.

The solar wind speed was at Background levels but with a rising trend, from the low 300s of km/s to peak near 375. The solar wind density started within single figures ppcc, but with a peak of around 30ppcc observed at 19/2130UTC. This was a precursor to a step-wise change upwards in IMF, with a flat 5nT previously observed rising to a peak of 16nT. The north-south component was initially small scale and stable, but this gave way to a larger magnitude and mostly anti-aligned behaviour (with Earth's field) in the UTC evening, with a peak of -15nT versus an earlier more modest +6nT. The phi angle was mostly positive (away from the Sun), but became tenuously negative after 19/2300UTC, perhaps suggesting CH03/- has arrived. This will become clearer in the coming hours.

The net effect of the above solar wind measures was for Quiet to Unsettled activity, with a provisional peak of Kp '4o' in the 21-24UTC interval.

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV), as measured at GOES16 continued its slow decline in the wake of 16 May's M9.6 from AR3310, and is now very near resting Background levels, having peaked at 0.8pfu - i.e. roughly a decade below S1.

High energy electron flux (greater than 2MeV), as measured at GOES16 was at Normal Background to Moderate levels, with a peak of around 300pfu at 19/1735UTC. The 24-hour integrated fluence has been well below Active levels. At 20/0001UTC, 4.04e6 integrated pfu was recorded.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is Likely to remain Moderate, with a Slight Chance of X-class throughout the period, AR3310 and AR3311 being the most likely sources of these flares. No new large regions are expected to arrive, however AR3305 leaves the disc by day four, leading to a slight decrease in flare risk by the very end of the forecast.

Solar Wind / Geomagnetic Activity: The only CME that features in the forecast is a southwest quadrant filament eruption from 17 May - possibly glancing Earth on or after the middle of the UTC day of Sunday 21 May to give a Slight Chance of G1.

In terms of fast winds, a minor coronal hole - CH03/- may affect Earth shortly, but is not likely to be impactful, perhaps offering a Chance of Active intervals over the current UTC weekend. More significant are CH05/- or more likely CH06/-, the latter of which may round-out the four-day forecast with a Slight Chance of G1.

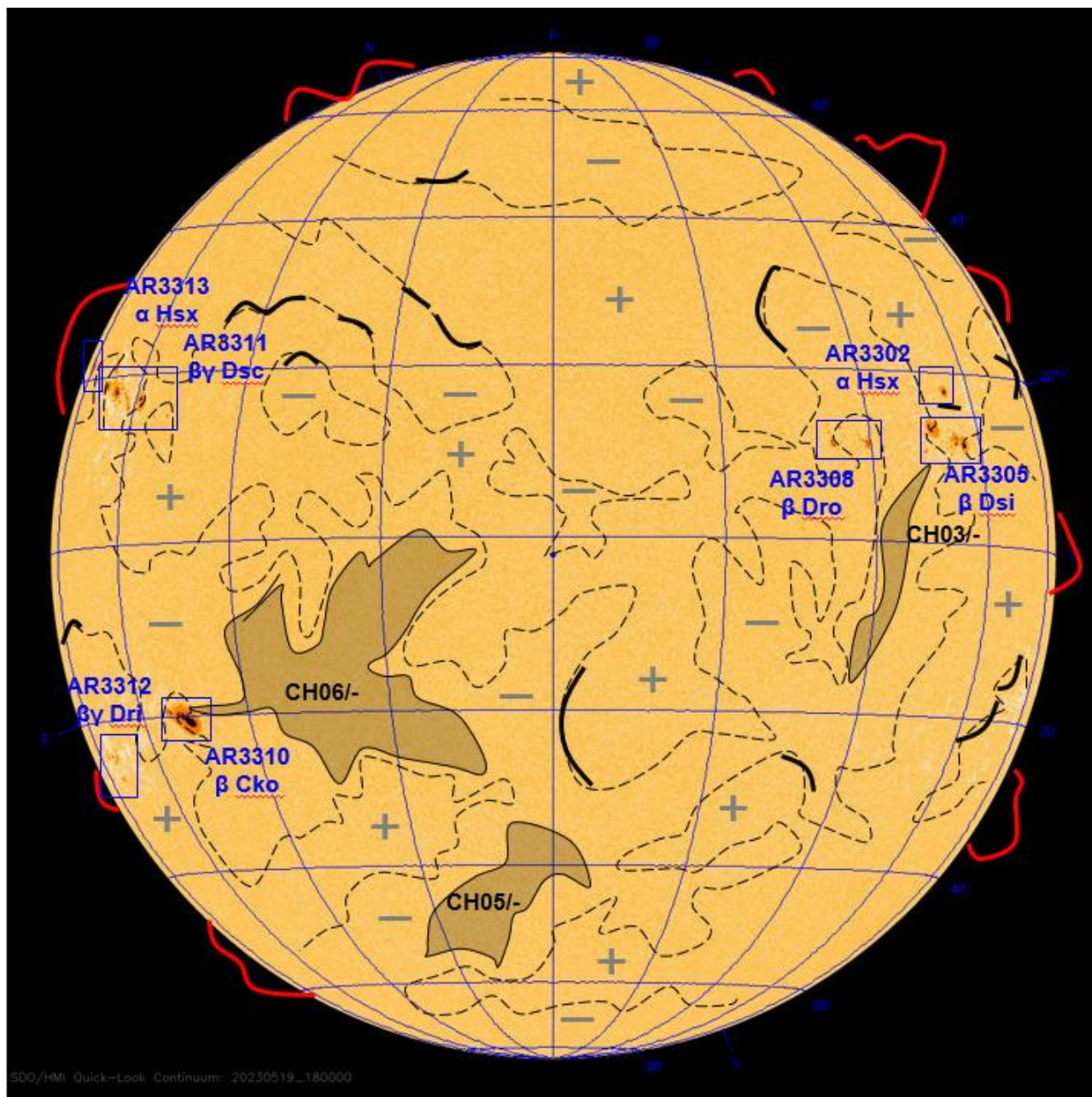
Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux carries

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a daily Slight Chance of S1, largely as a result of the eastern hemisphere spots, with this very gradually rising over the four days.

High energy electron flux (greater than 2MeV) will most likely remain at Normal Background levels throughout.

Figure 1. Solar Analysis Valid 19/1800UTC.



Key: Filament —, Prominence —, Magnetic Field Line - - -, Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Geomagnetic Storms:

One CME features in the forecast at present. A filament eruption triggered by activity from AR3309 was seen leaving the southwestern quadrant of the Sun on 17 May. While the deterministic MOSWOC Enlil run is a miss, a significant minority of ensemble members display a glance on or after the middle of that UTC day. This may result in residual effects into the new working week, but with a peak Slight Chance of G1 on day two, Sunday 17 May.

The coronal hole forecast is relatively low confidence for the period. Visually minor CH03/- is perhaps due imminently at Earth, and although it is a persistent feature with a very similar appearance on AIA211 to last pass, a CME-driven G4 arriving at that time completely masked any hints as to its capability, such that it is something of an unknown quantity on this outing. MOSWOC Enlil has backtracked in recent suggestions of a 450-500km/s fast wind due late on 19 May, although something of this ilk is considered possible from day one, Saturday 20 May, perhaps giving Active intervals given our approach to the solstice and its muting effect on coronal holes generally.

The only other features potentially due in the period are the near south polar CH05/-, which in all likelihood is too far from the ecliptic to feature, else CH06/-, which is visually larger and more intense than CH03/-, perhaps having slightly progressed on the solar disc relative to its last pass of Earth. All considered, a fast wind in the region of 550-600km/s is considered possible by the time the front edge reaches 40 degrees west on the solar disc, which would mainly feature within the UTC day of Tuesday 23 May, giving a further Slight Chance of G1.

Geo-Magnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	No	20	20	5	20
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
18/0316	Partial	Filament Eruption	SW	406km/s	21/1200UTC	Most likely miss, else glancing blow

Figure 2: MOSWOC Enlil run and ensemble showing an unperturbed deterministic, but with some ensemble members showing slight glances from the 17 May southwest quadrant filament CME.

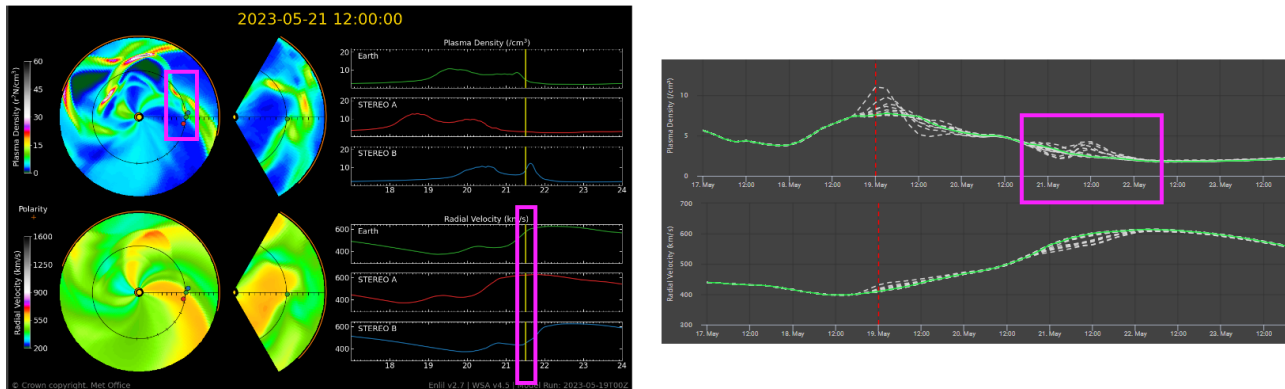
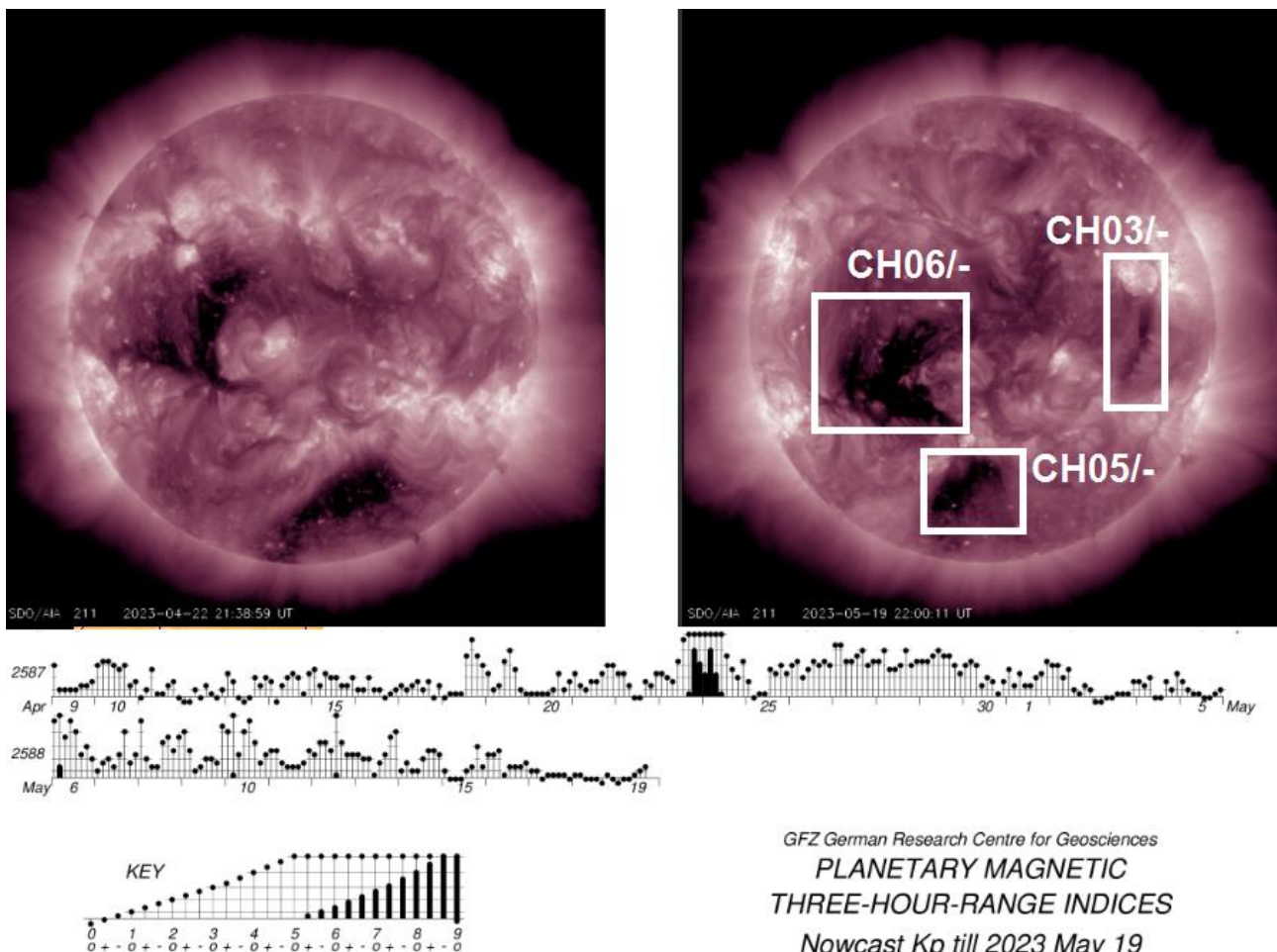


Figure 3: AIA211 imagery from past and current rotations, showing similar guise of CH03 and slight progression of CH06/-. Also shown is the Potsdam Kp index through the period, with the CME-driven G4 dominating the signal through CH03's predecessor's tenure.



GFZ German Research Centre for Geosciences
**PLANETARY MAGNETIC
 THREE-HOUR-RANGE INDICES**
 Nowcast Kp till 2023 May 19

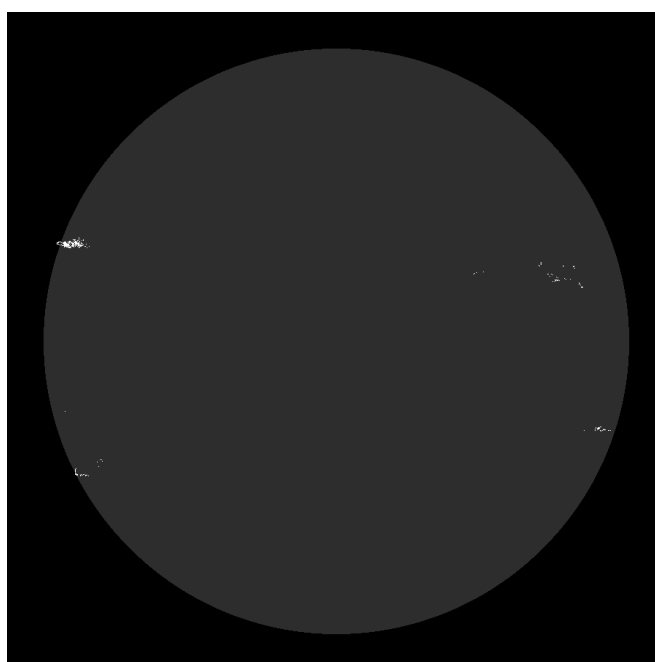
Radio Blackouts - X-Ray Flares:

The eastern hemisphere duo of AR3310 and AR3311 are by far the most likely sunspot groups to uphold currently observed solar activity in the period. Of the two, AR3311 has proven more temperamental in consistently delivering occasional high C and low M-class activity. By contrast, its southern neighbour, AR3310 delivered its M9.6 from around a day behind the limb, which in all likelihood means that the portion observable from Earth was only a fraction of its peak flux. While these two regions dominate the risks, the main growth trend in the period was again in the western sunspot group AR3305, which again saw no significant flare activity despite reasonable complexity and some proliferation of spots.

All considered, solar activity is Likely to remain Moderate, with a Slight Chance of X-class throughout the period. These risks have been tuned upwards slightly relative to the raw values, in part because AR3311's proximity to the limb is making it harder to discern any Mt Wilson delta spots. In terms of the evolution, no new large regions are expected to arrive, however AR3305 leaves the disc by day four, leading to a slight decrease in flare risk by the very end of the forecast.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	70	70	70	60
Very Active	R3 to R5 X Class	No	15	15	15	10

Figure 4: Sources of X-ray flare activity of C-class and above in the past 24 hours (courtesy of SIDC ROB). AR3311 in the northeast can be seen to be dominant.



Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux, as observed by GOES16 is now gradually relaxing back towards Background levels, having been slightly enhanced in the wake of the M9.6 flare from 16 May.

AR3310 and AR3311 are currently the most likely sources for any further enhancements, and to a lesser extent AR3305. The risk of high energy proton events is therefore not negligible, and increases slightly through the period with the main groups' transit westwards.

Radiation Storms	Level ($\text{cm}^{-2} \text{sr}^{-1} \text{s}^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	$\geq \text{S1}$	No	10	10	15	15
Very Active	$\geq \text{S3}^*$	No	1	1	1	1

* $\text{S3} \geq 10 \text{ MeV} \geq 1000 \text{ pfu}$ and / or $\geq 50 \text{ MeV} \geq 10 \text{ pfu}$. (pfu = $\text{cm}^{-2}\text{sr}^{-1}\text{s}^{-1}$)

Figure 5: Past week in GOES16 high energy electrons and X-ray flux, showing a 0.8pfu peak response to the 19 May M9.6 flare from AR3310.



High Energy Electrons Event ($\geq 2\text{MeV}$):

The high energy electron flux (greater than 2MeV) has remained mainly at Normal Background levels over the past 24 hours.

The forecast for the coming four days is relatively low confidence in terms of electrons. This is due to uncertainties as to the capability of CH03 discussed in the 'Geomagnetic Storms' section, and then the risk of the 17 May CME. The most likely driver of higher flux levels in the four days is not expected until the new UTC working week in the form of CH06. whereupon a 550-600km/s fast wind may eventually prove capable of delivering Active 24-hour fluence, although not in the current four-day forecast window, instead being nearer midweek.

Given the pollution of persistent coronal hole's effects due to CME activity on past and current rotations, MOSWOC REFM is not considered likely to offer good guidance until nearer the middle of the coming working week - assuming no new transients are emitted.

GEO Electron Environment	Level ($\text{cm}^{-2} \text{sr}^{-1} \text{day}^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	$\geq 2 \text{ MeV}$ $\geq 1 \times 10^8$	No	1	1	10	5
Very Active	$\geq 2 \text{ MeV}$ $\geq 1 \times 10^9$	No	1	1	1	1